Calculation and Design of an Experimental Verification of Coaxial Gyrotron with Two Beams

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***Abstract*—Theoretical studies and computer simulation show that the coaxial gyrotron with two electron beams (CGTB) can increase the output power of gyrotron and even can operate at dual frequency. In this paper, calculation and design of a coaxial gyrotron with two beams is presented for the experimental verification.**

I. INTRODUCTION

The study on gyrotrons remains to be one of the most attractive topics in modern science and technology for the following important motivations: due to the demand of very high radio frequency (rf) power for the magnetic nuclear fusion research, the ITER program requires 1-2 MW continuous-wave (CW) at 127.5 GHz and 170 GHz frequency, and high power is also needed for a varieties of applications including those in terahertz science and technology[1-3]. However, up to now a real CW 1-2 MW gyrotron has not been achieved yet.

The coaxial cavity gyrotron with two electron beams (CGTB) is proposed in order to increase the output power and improve mode competition[4]. And the dual frequency operation (DFO) of CGTB is presented[5]. It is a special operation of CGTB: one beam works at the first harmonic (ω_c) while another at the high harmonic ($l\omega_c$) in one cavity. There are two modes and two beams in the coaxial cavity; hence the cavity should be in degeneration. Dual frequency radiation can be obtained by using one gyrotron.

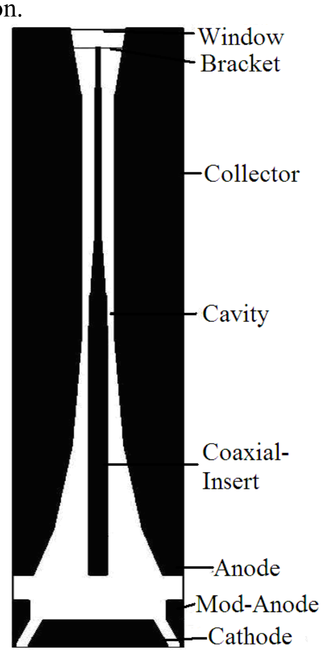

Fig.1 Schematic of the coaxial cavity gyrotron with two electron beams

II. GYROTRON DESIGN FEATURES

The gyrotrons were optimized to operate at the first harmonic $TE_{0.2}$ mode at 110GHz frequency and the second harmonic $TE_{0.4}$ mode at 220GHz frequency, and a coaxial magnetron injection gun with two beams is designed. It is a modification of the conventional coaxial magnetron injection gun (CMIG)[6], There are two emitting belts on the surfaces of the cathode. Schematic of the gyrotron are shown in Fig.1 and main parameters of gyrotron are shown in Table I.

TABLE I
MAIN PARAMETERS OF CGTB

Operation frequency	110GHz/220GHz
Cathode voltage	-40kV
Mod-Anode voltage	-20kV
Body(anode + insert) voltage	0kV
Beam current, I_{b1}/I_{b2}	10A/10A
Current density at the emitter	10A/cm^2
Beam radius in the cavity, R_{b1}/R_{b2}	4.85mm/5.53mm
Magnetic field in the cavity	4.2Tesla
Magnetic compression ratio	21
Pitch-ratio at the input of cavity, α	1.0
Electric field at the emitter surface	44 kV/cm

The parameter of the electron gun has been optimized using the MAGIC code[7]. Fig.2 shows the electron beam trajectories.

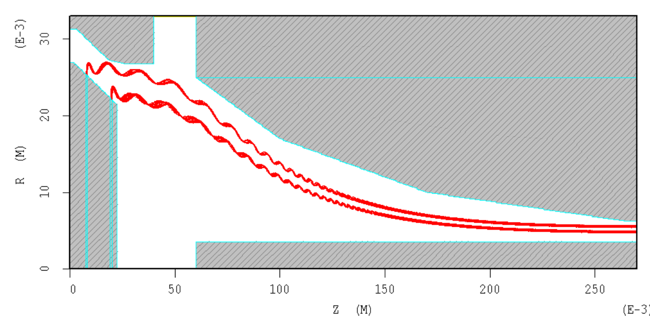

Fig.2 MIG Electron trajectories of the electron gun

A conventional axial output is adopted in this gyrotron. The mode competition of CGTB is carefully studied by means of the time dependent multi-mode competition nonlinear theory[5]. The results are shown in Fig.3, it shows two beams can excite TE_{02} and TE_{04} modes in a coaxial cavity simultaneously. The main competing modes of the first harmonic TE_{02} mode are TE_{13}, TE_{23} and those of the second harmonic TE_{04} mode are $TE_{13,4}$, $TE_{14,4}$, $TE_{1,5}$.

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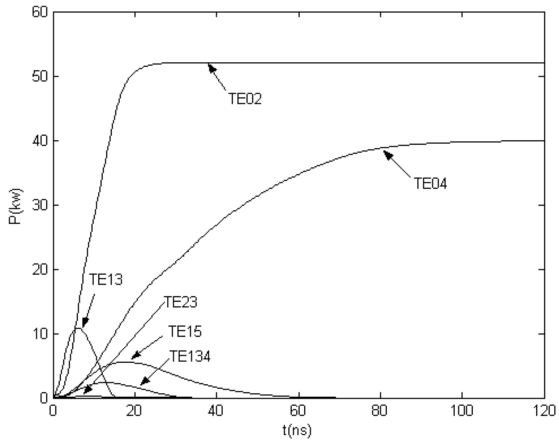

Fig.3 Mode competition of CGTB based on the time dependent multi-mode competition nonlinear theory.

The computer simulation on CGTB with DFO is carried out by using MAGIC code. The results are shown in Fig.4 - Fig.6. Fig.4 shows the output spectrum where the spectra of two frequencies can be seen clearly. Fig.5 shows the total output power of CGTB with DFO. From Fig.5 it is found that the first harmonic excitation starts at 10ns, the output power reaches to about 50kW, but the second harmonic starts with 60ns delay, and total output power reaches to about 40kW. Fig.6 shows phase space for particles.

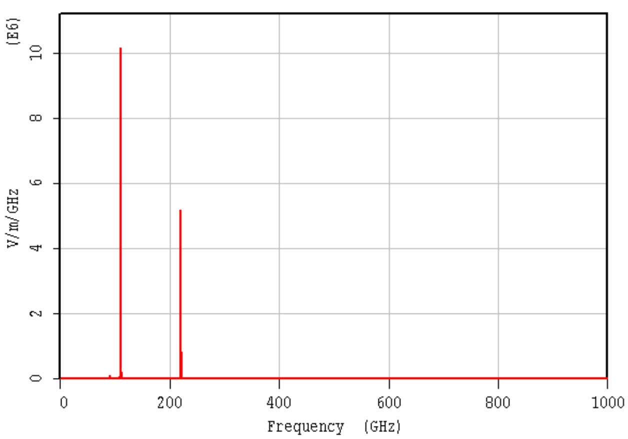

Fig.4 The output spectra of CGTB

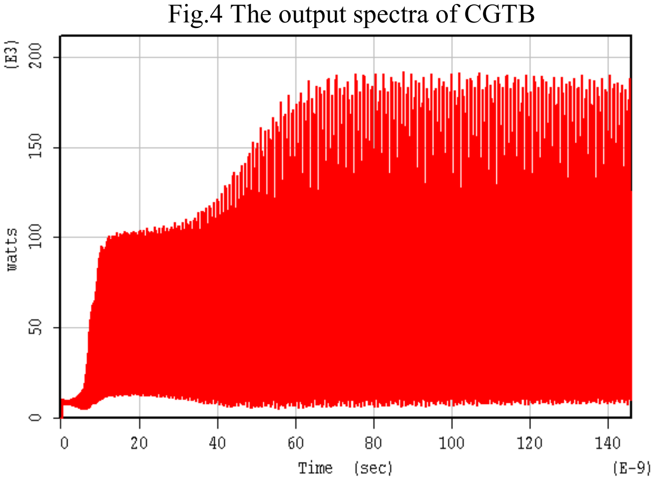

Fig.5 The total output power of CGTB

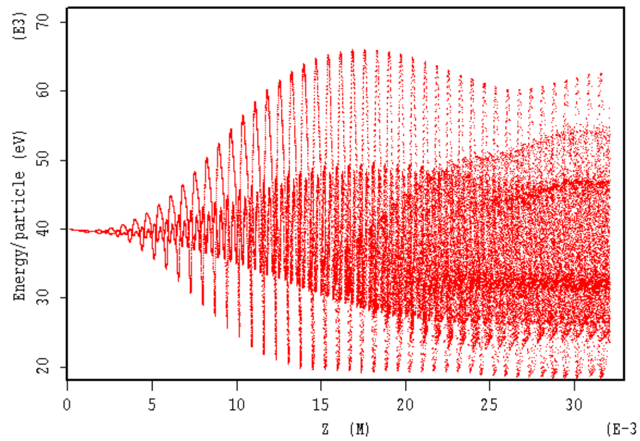

Fig.6 Phase space for particles

III. CONCLUSION

A CGTB with dual frequency operation is designed in this paper. A cavity with a cylindrical outer wall and a tapered inner rod was used. The results of calculation and simulation show that CGTB can operate at two different frequencies with high power simultaneously. The first harmonic output power of 50kW has been measured in $TE_{0,2}$ mode at 110GHz with an efficiency of 12.5% and the second harmonic output power of 40kW has been measured in $TE_{0,4}$ mode at 220GHz with an efficiency of 10%.

ACKNOWLEDGMENTS

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